RESEARCH BULLETIN

FURTHER IMPLICATIONS OF MUNDY-CASTLE'S CORRELATIONS BETWEEN EEG AND WECHSLER-BELLEVUE VARIABLES

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between EEG and Wechsler-Bellevue Variables

Abstract

Factor analysis is re-applied, using relatively more rigorous methods, to a 15 x 15 correlation matrix reported by Mundy-Castle and containing 11 Wechsler-Bellevue subtest variables, 2 EEG variables, age and occupational level, for a sample of 34 employees of the South African National Institute for Personnel Research. Six common factors were extracted and subjected to orthogonal rotation in search of meaningful simple structure.

Two age-related factors were found and respectively identified as "Experience" and "Deterioration." (Factors I and II.)

Within the residual four-space, the vectors for alpha Frequency in the EEG and Digit Span performance in the W-B were found to be comparable. (Factor III.) This result is discussed in relation to the excitability cycle hypothesis, primary *vs*. secondary function, and externalization *vs*. internalization.

The vector for alpha Index was found to have a near perfect communality in the residual three-space, and is interpreted as measuring (inversely) strength of "Conditioned Attentiveness." (Factor IV.) Picture Completion in the W-B is judged to depend partially on this factor.

The remaining two factors are of minor interest since they are probably mixtures of things that could not be distinguished in this study using only 15 variables and 34 cases.

It is suggested that a proper interpretation for common factors, when there have not been enough variables to preclude the existence of specific factors, is in terms of dynamic mechanisms presumptive of a cause-effect relationship between loaded variables, rather than in terms of hypothetical underlying variables. Factors I, IV, and V can be used to illustrate this principle.

Further Implications of Mundy-Castle's Correlations between EEG and Wechsler-Bellevue Variables[1]

The general hypothesis that stable relationships exist between certain aspects of "intelligence" and certain aspects of the electroencephalogram (EEG) is inherently plausible. In an effort to spell out more specifically the possible nature of such relationships we were led to consider a report by Mundy-Castle (26), based on data that are directly relevant to the general hypothesis. Mundy-Castle describes the results of a factor analysis of a correlation matrix involving both EEG and Wechsler-Bellevue subtest (W-B) variables, and exhibits evidence which is at least indicative of the existence of some relationship.

Unfortunately, when we tried to use these reported results in order to spell out more precise and testable hypotheses, we were forced to recognize the presence of logical and computational mistakes in the design and execution of Mundy-Castle's factor analysis. Since these are of such a nature as to be fairly obvious to one familiar with conventional procedures for factor analysis, there is some danger that the value of the reported data will be unduly discounted on these grounds.

It is the purpose of this paper to describe the procedures, the results obtained and an interpretation of these results for a completely independent factor analysis of Mundy-Castle's data, commencing from the previously reported correlation matrix. This material is preceded by a summary and critique of Mundy-Castle's reported results.

Mundy-Castle's Results

On the basis of a variety of theoretical and empirical considerations, Mundy-Castle was led to seek in the files of the South African National Institute for Personnel Research (NIPR) for the records of any individuals who had been subjected to EEG observation and who also had completed the

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South African version of the Wechsler-Bellevue Intelligence Scale. A total of 25 female and 9 male cases was found, all but three of whom were employees of the NIPR in various professional and sub-professional categories. While both the EEG and W-B data had been previously collected, these had been gathered independently by different workers for other purposes and the observations had not previously been correlated. For some of the subjects, as much as 18 months intervened between the collection of the two kinds of data.

Product-moment intercorrelations were computed for 18 variables, and were reported to three decimals (26). These values are reproduced in our Table 1. Means and standard deviations for most of the variables (28) are also reported in Table 1. The first 11 variables are the W-B subtests, which may be described as paralleling their American counterparts (40), as follows:

1. Information (I)
2. Comprehension (C)
3. Arithmetic (A)
4. Digit Span (D)
5. Similarities (S)
6. Vocabulary (V)
7. Picture Completion (PC)
8. Object Assembly (OA)
9. Block Designs (BD)
10. Digit Symbol (DS)
11. Picture Arrangement (PA)

The next three variables are also derived from the W-B by well-known, standard procedures. They are:

12. Verbal Intelligence (VIQ)
13. Performance Intelligence (PIQ)
14. Total-Scale Intelligence (TIQ)

Variables 15 and 17 are derived from the EEG records, and are measures of the mean frequency of the observable occipital alpha rhythm when the subject is relaxing with his eyes shut under what are taken to be standard

Table 1.

RAW INTERCORRELATION MATRIX (N = 34)

	Ī	C	A	D	S	V	PC	OA	BD	DS	PA	VIQ	PIQ	TIQ	αF	Age	αI	OL	μ	σ	Units
Ī	-	441	216	-080	166	394	052	-136	057	-054	-248	504	148	356	294	588	241	404	13.0	1.5	WTS
C	441	-	-188	-127	119	435	087	-039	-197	-328	-403	304	-215	025	179	320	-163	-204	13.4	2.0	WTS
A	216	-188	-	336	-057	081	-119	033	194	295	002	689	121	499	140	005	475	460	14.5	3.6	WTS
D	-080	-127	336	-	099	029	055	260	420	388	063	601	257	588	196	-317	080	117	13.7	2.7	WTS
S	166	119	-057	099	-	281	-067	177	053	-069	-175	340	118	304	218	191	176	082	16.5	1.3	WTS
V	394	435	081	029	281	-	-185	-137	-355	-027	-098	373	-182	094	406	360	-006	047	13.0	1.7	WTS
PC	052	087	-119	055	-067	-185	-	365	354	-064	138	-034	578	384	190	-008	-434	-092	13.7	1.6	WTS
OA	-136	-039	033	260	177	-137	365	-	338	-210	135	214	539	520	413	-140	-023	-169	10.5	2.4	WTS
BD	057	-197	194	420	053	-355	354	338	-	413	073	250	700	634	196	-218	084	129	14.0	2.3	WTS
DS	-054	-328	295	388	-069	-027	-064	-210	413	-	177	164	319	336	-082	-198	041	292	13.0	2.1	WTS
PA	-248	-403	002	063	-175	-098	138	135	073	177	-	-170	441	189	103	-138	-413	312	11.0	2.3	WTS
VIQ	504	304	689	601	340	373	-034	214	250	164	-170	-	184	748	417	116	333	308	-	-	WIQ
PIQ	148	-215	121	257	118	-182	578	539	700	319	441	184	-	775	403	197	-166	278	-	-	WIQ
TIQ	356	025	499	588	304	094	384	520	634	336	189	748	775	-	507	125	098	330	126.5	6.1	WIQ
αF	294	179	140	196	218	406	190	413	196	-082	103	417	403	507	-	265	-269	-184	-	-	cps.
Age	588	320	005	-317	191	360	-008	-140	-218	-198	-138	116	197	125	265	-	073	285	24.2	7.0	yrs.
αI	241	-163	475	080	176	-006	-434	-023	084	041	-413	333	-166	098	-269	073	-	213	-	-	%
OL	404	-204	460	117	082	047	-092	-169	129	292	312	308	278	330	-184	285	213	-	2.7	1.1	-

conditions, and of the percentage of time that such a rhythm is observable. (An alpha wave may be defined as any wave which is in the frequency range 8 - 13 cycles per second and which is of relatively high amplitude.) Thus we have:

15. Alpha Frequency (αF)
16. Chronological Age (Age)
17. Alpha Index (αI)

The final variable is referred to in Mundy-Castle's <u>tables</u> as "Occupational Seniority" but is described in his <u>text</u> as a "five-point classification of occupational level," presumably reflecting a status hierarchy within the NIPR. Thus:

18. Occupational Level (OL)

Mundy-Castle then reports applying the Thurstone complete centroid method of factor analysis to this matrix, stopping after five factors and reiterating the entire analysis once in order to stabilize the communality estimates. This was followed by orthogonal rotation toward simple structure, ending with the results that are reproduced in our Table 2. This table gives the correlation of each variable with each of the five rotated factors, together with the communality obtained for each variable and a measure of the importance of each factor in accounting for variance. (The latter values have been computed by us as the sums of squares of factor loadings for each <u>factor</u>, <u>ex</u>cluding VIQ, PIQ, and TIQ.)

Mundy-Castle offers the following "tentative interpretations" of these factors:

A: Visual-concrete aspect of intelligence.
B: Verbal-abstract aspect of intelligence.
C: Age component in intelligence.
D: Temperamental component in intelligence (central excitability factor).
E: Not interpreted.

Table 2.

MUNDY-CASTLE'S ROTATED FACTOR MATRIX

	A	B	C	D	E	h^2
I	079	311	821	033	-295	865
C	-080	-161	602	190	222	480
A	-147	625	-026	395	-173	599
D	168	404	259	572	042	587
S	086	253	286	030	271	228
V	-179	-009	608	355	041	529
PC	643	-212	043	052	-062	467
OA	525	105	-076	158	477	545
BD	638	492	-321	027	-064	757
DS	102	312	-308	140	-466	439
PA	285	-177	-309	147	-386	379
VIQ	-063	760	416	616	035	1.135
PIQ	1.010	242	009	-026	-156	1.104
TIQ	675	585	030	639	-062	1.211
αF	418	-029	361	502	218	605
Age	089	015	731	-124	-222	607
αI	-332	665	025	-199	194	630
OL	016	-383	-109	-057	653	588
Σa^2	1.583	1.757	2.534	1.027	1.406	8.305

Critique of the Previous Analysis

Superficially, the most plausible point for possible criticism of Mundy-Castle's analysis is his use of so few cases. Certainly 34 cases is a comparatively small number, and certainly it would have been desirable to use any additional cases that might have been found. Nevertheless, it *is* very much within the realm of possibility for these data to determine five or even more than five factors. If an efficient and rigorous method of factor extraction is employed, there will be appropriate tests of statistical significance for the number of factors, and we would normally prefer to see the results of such a significance test as the basis for any judgment of this kind.

A second likely point for criticism is the decision to include VIQ, PIQ, and TIQ in the factor analysis, along with all the other variables from which they are computed. This is a much more serious flaw than simply the use of few cases. One effect of including these measures, which are dependent on other included measures, is to bring not only the specific factors for the W-B subtests into the common-factor space, but also their errors of measurement. Regardless of what Table 2 may show, the communalities for all 13 of the W-B variables involved in these interdependencies should have been found to be virtually unity. (Vocabulary appears not to have been used in the IQ computations.) Of course, it also follows that one would expect to extract at least ten factors in order to use up this much communality for all of the W-B variables, whereas only five have been extracted. However, it seems clear that the communality estimates of the 13 implicated W-B variables have been undesirably inflated by this mechanism, and that the communality estimates for the five remaining variables do not merely suffer by comparison but have actually been systematically deflated. This deflation is a necessary concomitant effect, since the factor matrix has to predict the correlations between W-B and non-W-B variables at about their observed values in Table 1. Thus, the significance of the non-W-B variables may have been seriously *under*-estimated!

A corollary and still more disquieting consequence of the inclusion of VIQ, PIQ, and TIQ is that this may have led to the extraction of too many factors, since this would be the only way to use up very much of the surplus communality. Published factor analyses of the W-B subtests based on communality estimates and even using much larger samples have usually yielded only three factors (1, 4, 6, 7, 16, 17, 18, 19, 20, 37). This would seem to place the burden of proof on the present data to demonstrate that three factors are actually insufficient, but the possibility of providing such proof has been frustrated by the inclusion of the experimentally dependent variables in the correlation matrix that has been factored. It was primarily in view of this possibility, and with the suspicion that three or four factors at most would suffice, that we felt the necessity of performing a completely independent factor analysis of the reported intercorrelations.

On the other hand, we must note that several recent factor analyses have found evidence for more than three factors within the Wechsler battery of eleven subtests. Cohen (8, 9, 10) reports a number of analyses with five factors, Davis (13) reports a ten-factor structure in which every factor is correlated with one or more of the W-B subtests, and Saunders (33, 34) reports that the WAIS battery alone spans at least ten significant dimensions, even with the Vocabulary test excluded. The only interpretation consistent with all of the reported data is one which emphasizes the reliable unique variance of each subtest; whenever a sufficient number of variables have been included in a factor analysis involving Wechsler subtests, these uniquenesses in the subtests have asserted themselves.

In this context, the question must therefore be raised as to the meaning of factors extracted from a matrix that is not large enough to permit separation of these uniquenesses. This is precisely the situation behind the factors which have traditionally been interpreted in terms of underlying "primary abilities"; the typical three factors have usually been labelled as verbal, numerical and performance skills, or something meaning the same thing. Factors appearing to warrant these labels have

been found with a high degree of regularity. An alternative interpretation is possible, however, which is that the particular patterns of loadings found for these factors reflect the existence of certain modal mechanisms governing the dynamic[2] interplay of distinct mental functions. In other words, remembering that a factor is merely a theoretical construct whose utility is to facilitate explanation of intercorrelation in a variety of situations, it is just as reasonable to regard some of the factor loadings as being caused by others, as to regard them all as manifestations of some hypothetical underlying variable which "is" the factor. It is quite conceivable, moreover, that some of the intervening portions of a given dynamic mechanism are not present in a particular instance among the observations subjected to factor analysis. Such dynamic mechanisms, if they exist, will be of as much interest to personality theorists as to anybody.

The prospective interpretation of factors emerging from smaller matrices as dynamic mechanisms involving distinct functions, rather than as functionally unitary entities, has several notable advantages. First, it circumvents the necessity of inventing any name for the hypothetical entities, and can account for the great difficulties often encountered in efforts to build even one "pure" test for such an entity. Second, it can account for the disappearance of these entities in factor analyses which have embodied larger numbers of variables, _i.e._, they are _at least_ relegated to second-order status and may disappear altogether, in any event altering the apparent nature of the results. Third, it anticipates that factor patterns may change as a function of moderator variables (31), such as age, for example. While the meaning of an underlying ability should remain constant, the personality mechanisms that are available to adults and accepted in adults by others are not the same as those for children.

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[2] "Dynamic" is a word with varied connotations among psychologists. We use it simply as an engineering term referring to the _constantly changing resolution_ of forces within a mechanical system that is doing something.

Fourth, it can account for the complete disarrangement of the typical three-factor pattern even in adults when samples atypical of the general population are chosen, whereas, if a factor simply reflects a structural entity, no manner of selection can cause its constituents to become separated. Fifth, it leads directly to the design of studies aimed at determining the direction of the cause-effect relationships within particular dynamic mechanisms, and to the eventual identification of certain already available measures as being relatively more fundamental than others.[3]

In view of the strongly biased nature of Mundy-Castle's sample of subjects, and the relatively small number of operationally independent measures available for his sample, factor analysis of the data should be undertaken only with the expectation of depicting an atypical set of interesting adjustment mechanisms, and perhaps of gaining information suggesting that certain specific Wechsler subtests are as fundamental as the EEG. Such suggestions would serve to spell out our general hypothesis. We do not expect to prove anything, unless it be the feasibility and desirability of obtaining further results in this area.

Procedure for Reanalysis

The correlation matrix that we have factored contains 15 of the 18 variables reported by Mundy-Castle, and may be abstracted from Table 1 simply by omitting VIQ, PIQ, and TIQ. Following the procedure suggested by Wrigley (41), zero was used as the initial communality estimate for each variable. Factors were then extracted using the principal axis method and an electronic computer. The factor analysis was reiterated a total of twelve times using successively improved communality estimates. Following each iteration, as many factors were accepted as significant as

[3] The points outlined in this paragraph appear not to be generally recognized, even by factor analysts. Proper treatment of these issues as issues obviously requires much more space than is available here, and would be merely tangential to the purpose of this paper.

yielded positive latent roots greater in magnitude than the largest negative latent root in the same set; this rule-of-thumb led unambiguously to the final acceptance of six factors. Inasmuch as the "reality" of the situation probably calls for at least ten factors from the Wechsler tests alone (33, 34), and there is no prospect of determining this many factors with so few variables, we do not report any statistical test of significance for the number of factors.

The unrotated factors resulting from this factor analysis are reported in Table 3, in order of their decreasing contribution to variance. It will be seen that the six factors taken together account for approximately two-thirds of the total variance of the 15 measures included in the analysis. However, the communalities of the variables range widely, from a low of 0.156 to a high of 0.993.

The factors were initially rotated according to the quartimax criterion for simple structure (29). However, since the quartimax procedure is completely blind, it was not expected to yield the most generally meaningful positions for the axes. Particularly in a matrix with so few variables as the present one, and which had not been designed as a factor analysis from the start, any purely objective formulation of simple structure is capable of capitalizing upon the absence of relevant variables from the study, and of presenting the investigator with a result that is <u>too</u> simple to be sustained in cross-validation in a broader context. While we would maintain that a meaningful rotation in factor analysis should normally be expected to exhibit a degree of simple structure, we do not believe that it is sufficient to focus on this as the sole basis for rotation in an exploratory study.

Accordingly, other rotational positions were explored by formulating hypothesized patterns of factor loadings and seeing in each case how closely the data could be brought into conformity with the hypothesis (35). The results reported in Table 4 were judged to yield a satisfactory interpretation of factors, in addition to exhibiting a satisfactory simple structure. Since the factors in Table 4 contribute about equally to the total variance of the factor matrix, they have been arranged and numbered

Table 3.

PRINCIPAL COMMON FACTORS

	F_1	F_2	F_3	F_4	F_5	F_6	h^2
I	696	417	244	101	304	141	840
C	622	-242	188	-117	045	268	568
A	-040	656	056	-039	-101	-090	455
D	-326	385	343	-174	-304	158	519
S	246	123	182	-167	-089	-107	156
V	656	090	191	132	-517	035	761
PC	-178	-212	518	067	374	112	502
OA	-231	-076	590	-331	073	-386	671
BD	-453	378	477	-196	264	242	743
DS	-367	481	010	190	-206	382	590
PA	-428	-005	189	615	-095	-304	699
αF	244	-002	756	-018	-245	-139	711
Age	666	116	101	223	218	-126	581
αI	158	658	-396	-561	062	-245	993
OL	046	699	-063	499	204	-132	803
λ	2.609	2.195	1.908	1.281	.892	.708	9.592

Table 4.

FINAL ORTHOGONAL FACTOR MATRIX

	I	II	III	IV	V	VI	h^2
I	903	008	-028	-130	-076	047	840
C	443	240	112	123	-523	-112	568
A	202	-382	073	-425	286	012	455
D	-092	-594	343	-167	008	113	519
S	201	055	250	-210	-075	-007	156
V	472	033	432	-042	-130	-576	761
PC	086	-020	148	415	-070	543	502
OA	-147	108	568	-096	051	550	671
BD	027	-569	104	-039	-010	638	743
DS	-024	-740	-097	013	159	-085	590
PA	-170	-106	173	412	677	019	699
αF	315	-010	768	101	-045	100	711
Age	680	324	002	-011	065	-095	581
αI	096	-043	-217	-966	037	021	993
OL	477	-279	-244	-128	649	-011	803
Σa^2	2.182	1.640	1.477	1.599	1.304	1.391	9.592

in an order that will facilitate discussion. Table 5 reports the transformation matrices relating the final rotated factors to the principal axes and to the quartimax axes.

Discussion

Since it is our judgment that Table 4 contains the most meaningful factorial representation of Mundy-Castle's correlation matrix, we propose to organize our discussion in terms of this particular set of factors.

Factor I: This factor is very similar to Mundy-Castle's Factor C, which he identified as the "age component in intelligence." In every rotational solution we examined, this is the dimension which accounted for more variance than any other. For a number of reasons, we prefer to regard Factor I as primarily an experience factor.

Certainly it is clear that not all of the recognized effects of age are subsumed within this factor. Some such effects will be seen to fall in Factor II, which we shall discuss next. Others may be seen to fall within what is, in this context, a specific factor, whose existence may be inferred from the wide gap between the communality of .581 for age and the substantially perfect reliability with which it is normally measured. There may be some unreliability for age in this study since the W-B and EEG data were not collected in a constant time relation to each other, but this could not account for as much unreliability as would have to be posited in this situation.

The concept of experience seems sufficiently broad to account in obvious fashion for all but one of the loadings on this factor, including those that are near zero as well as those that are high. The loading for alpha frequency is the only possible contradiction for this interpretation. However, despite our efforts to eliminate this loading, we were not able to find any satisfactory simple structure without it. At least two possible explanations of this situation may be suggested. One might be that there is a separate relation between alpha frequency and age that has become confounded with this factor because of the impossibility of distinguishing enough distinct factors with only 15 variables. Such a relation is known

Table 5.

TRANSFORMATION MATRICES

	I	II	III	IV	V	VI
F_1	744	440	069	-145	-295	-375
F_2	410	-585	-085	-581	379	038
F_3	308	-182	755	287	-053	466
F_4	270	-069	-145	659	610	-306
F_5	296	266	-542	093	037	733
F_6	152	-597	-321	341	-627	-094
Q_1	977	055	-123	013	-093	133
Q_2	-033	978	-078	-008	110	-156
Q_3	021	150	812	010	043	562
Q_4	-019	014	003	996	-081	-018
Q_5	102	-113	-010	083	984	-035
Q_6	-180	071	-565	016	049	800

to exist prior to age 15 or so (38) and, with opposite sign, beyond age 30 or so (14). At the age level of this sample there should not be any marked relation between alpha frequency and age as such. An alternative explanation might be that possession of a high alpha frequency actually does contribute to the efficiency with which time may be utilized to gain experience, and that alpha frequency is in this sense an integral part of an elaborate dynamic mechanism of the sort suggested above. The latter alternative is certainly consistent with the increasingly well-documented hypothesis that the alpha rhythm controls or reflects a master excitability cycle related to perception (5, 15, 21, 22). A higher frequency implies more cycles per second and each cycle may in some manner imply accomplishment of one unit of "perceptual work." In view of the availability of this alternative interpretation, we are content to identify Factor I as experience.

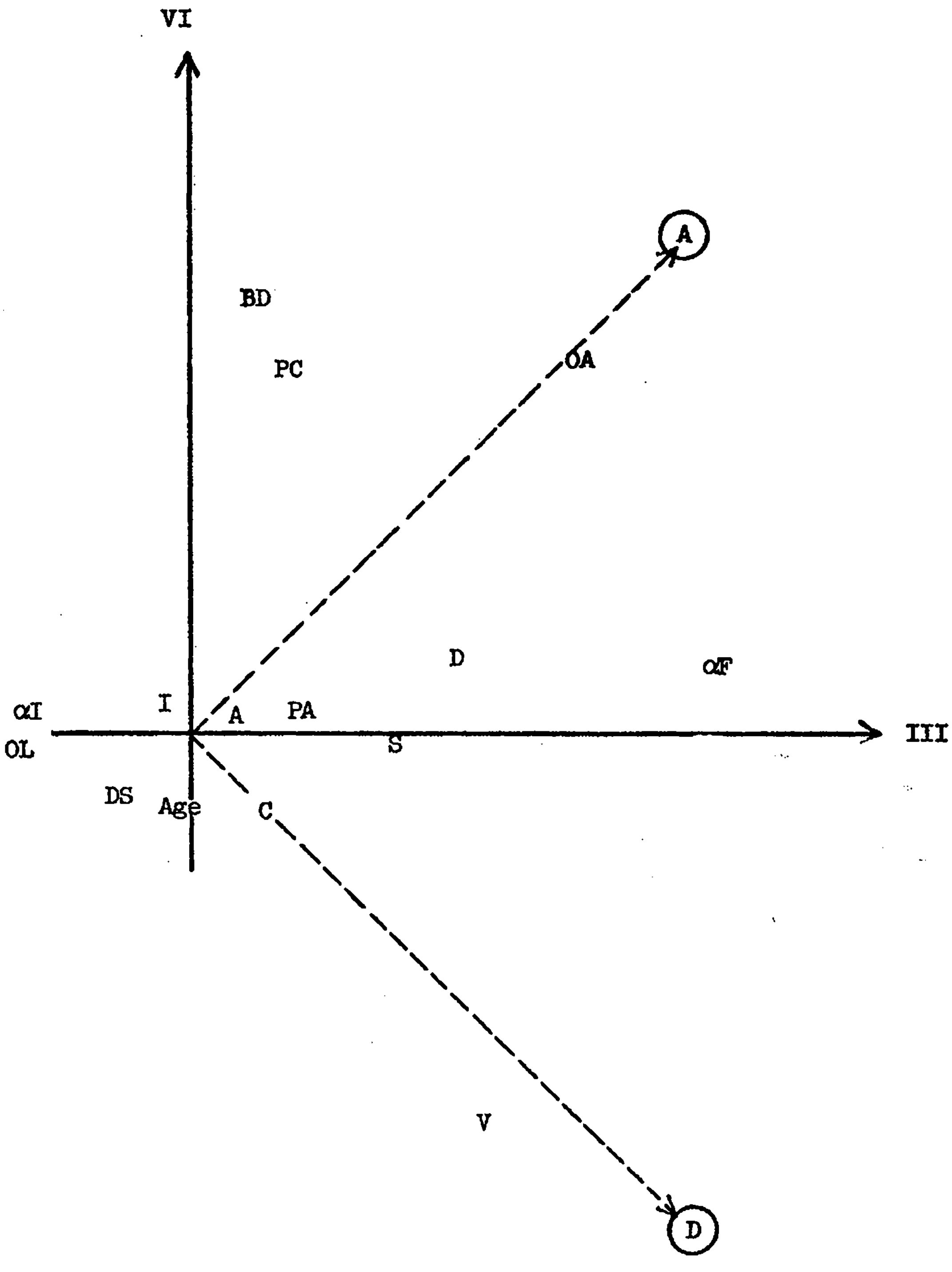
<u>Factor II</u>: Mundy-Castle's Factor B comes closest to this factor in his solution, but comes equally close to our Factor IV and is not a true match for either one. In an attempt to pivot a <u>single</u> factor on the age variable, this factor was deliberately merged with the first factor in a rotational trial which was then rejected as inadequate.

It seems clear that Factor II may be regarded as a <u>deterioration factor</u>. The four tests utilized by Wechsler as "don't hold" for the purpose of computing mental deterioration (40, pp. 65-67) are strongly negatively loaded on this factor, while all of the other tests have zero or possibly even positive loadings. It is of particular interest to note that neither of the EEG measures is related to this factor--an observation that seems to lend further support to our preferred interpretation of Factor I for, if we were concerned with a separate relation of age and alpha frequency, we should expect to find the latter loading <u>both</u> age-related factors.

<u>Factor III</u>: This factor seems to fall in Mundy-Castle's results about midway between his Factors A and D. Our Factor VI also appears to fall in the plane of Mundy-Castle's A and D, and it is of some interest to examine the factor-plot of Factor III with Factor VI, as shown in Figure 1.

Figure 1.

LOADINGS ON FACTORS III AND VI



Alpha frequency, Object Assembly performance, and Digit Span performance provide the three highest loadings for Factor III. Holding the effects of aging and experience constant, i.e., ignoring Factors I and II, all the important residual relations of these three highly loaded variables are depicted in Figure 1. From the figure it is apparent that Digit Span, rather than Object Assembly, provides the W-B measure most nearly comparable with alpha frequency. This seems to us the most important single result latent in Mundy-Castle's data, but one that was substantially obscured by the combination of influences affecting his analysis.

Immediate support for this conclusion is afforded by the finding of Shure and Holtzer (36), employing analysis of variance techniques and a sample of several hundred hospitalized males, that alpha frequency was significantly related only to Digit Span and Arithmetic among the W-B tests. The significance levels attained for Digit Span were considerably higher than those for Arithmetic; assuming D and A to have been correlated in his sample, holding D constant could also eliminate the significant effects observed using A.

It would appear from both these results that Digit Span may be measuring some mental function that is relatively fundamental and that this function may be of the same order of fundamental-ness as the alpha frequency observed in the EEG. Indeed, it is possible to formulate the meaning of Digit Span performance in terms that are highly suggestive of a direct relationship between it and alpha frequency, still regarding the alpha rhythm as a master excitability cycle controlling perception. Such a formulation requires a preliminary digression into the psychological nature of the Digit Span task beginning with the following distinction between "externalizing" and "internalizing":

"The task presented by Digit Span can be approached in two fundamentally different ways. One common way is for the subject to try to visualize the digits as though they were written on some blank surface available to him, be it a piece of paper, the wall of the room, the inside of his

eyelids, or what have you. Another common way, representative of the alternative approach, is for the subject to regroup the digits so that there are relatively fewer numbers to be kept in mind. The important difference between these two approaches is that one of them deals with the digits as if they only existed 'out there,' while the other spontaneously accepts... them internally. This is but one of several correlative distinctions that can theoretically be drawn between one person who is an 'externalizer' and another who is an 'internalizer.' For example, the externalizer has a relatively stronger 'need' for other people in his environment and will tend to seek interpersonal involvements. (The internalizer's rationalization would be that the presence of others helps the externalizer by holding before him aspects of reality which he would otherwise have to hold in his own mind.)...The externalizer's approach is naturally concrete and specific, while the internalizer's is naturally abstract and unconfined by the boundaries and attributes of a particular stimulus configuration." (32)

At this point it will be obvious to readers who are familiar with Mundy-Castle's use of the concepts of "primary function" and "secondary function" (3) that our externalizer is relying on primary function and our internalizer is relying on secondary function. To continue the quotation:

"Digit Span is useful as a personality test because, other things being equal, internalizers do better on it than externalizers....The phenomenon of differential performance may be readily verified by interviewing subjects, provided one is alert to certain complications arising in individuals who are strongly compensated in this area....In uncompensated cases, the interview report will correlate quite well with the deviation of the individual's Digit Span performance from his [profile].... However, most compensated externalizers quickly become aware of the fact that their natural approach through visualization is not working very well. Sooner or later they will shift their approach to one that looks more characteristic of an internalizer...."

Mundy-Castle reports a correlation of +.46 between ratings of usage of primary function and alpha frequency, for a sample of 40 cases similar to that used in the present study (24) and even overlapping it to the extent of 11 cases (28). Factor III, in turn, associates alpha frequency with high performance on Digit Span, which we have reason to interpret as internalization. Thus, empirically, ratings of primary function appear to be identified with internalization, and we emerge with a discrepancy in the signs of the various interrelationships. This discrepancy can be attributed to the fact that Mundy-Castle's samples are bound by their nature to involve a high average level of compensation, with more over- than undercompensated cases. The relatively high mean WTS score for Arithmetic, shown in Table 1, would support this attribution (32). This fact, coupled with the known difficulty, in any form of rating, of distinguishing the motivational basis of behavior from the behavior itself, suggests that the ratings were simply insufficiently penetrating. Behavior in an overcompensated group would be expected to show a negative correlation with its motivational base. In such a group, the majority of the externalizers will be striving with considerable success to look like internalizers, and vice versa.

We conclude, therefore, that the conceptual equivalence of externalizer versus internalizer and primary versus secondary function is consistent with the relationships that their measures have shown with alpha frequency, and that the conceptions may be appropriately blended with each other and with the excitability cycle hypothesis for the alpha rhythm. Further validation of this conclusion must now be sought.

The very substantial loading on Factor III for OA may not be interpreted without making some sort of assumption as to the meaning of OA. We have discussed OA elsewhere (32, 33, 34), regarding it as particularly sensitive to the influence of anxiety arising from situational uncertainty. Since it is relatively very unlikely that an externalizer lacking in this anxiety would seek employment in any sort of academic environment, we are able to account for the appearance of OA on this factor as an artifact stemming from the type of sample used.

<u>Factor IV</u>: This factor is similar to Mundy-Castle's Factor B, as was our Factor II. In view of the loading of .966 for alpha Index it is obvious that αI <u>is</u> this factor, and we may place some confidence in this result because of the relative care exercised in communality estimation for this analysis. What is of interest is that αI marks a "common" factor in this analysis with W-B tests, involving appreciable loadings for PA, PC, and A. It seems most likely that αI may be identified with one of the various mental functions tapped by these W-B tests, and that the other tests involve functions that are related only because of a dynamic mechanism prevalent in the selected sample.

One of the most striking features of the alpha rhythm is its tendency to become "blocked" when the individual is alert and attending to an external stimulus (27). This is why the EEG is typically studied in individuals who, while awake, are relaxing in a quiet room with their eyes shut. The blocking phenomenon is consistent with the excitability hypothesis; the intrusion of a prominent stimulus simply desynchronizes the rhythm to produce a more uniform level of attention. Alpha Index, then, is simply the proportion of time during which the <u>resting</u> alpha rhythm is unblocked and is observable instead.

The alpha rhythm is also observed to disappear, as though blocked, in individuals who are engaged in solving mental arithmetic problems (25, 27) or who are paying attention inwardly for other reasons (2).

Finally, it is known from animal and human experiments that the alpha blocking response may be conditioned (11, 23), although maintenance of the blocking response may also be subject to certain adaptation effects (12). We may conclude, therefore, that αI measures (inversely) a conditioned or habitual tendency of the individual to pay attention, either to external stimuli or to internal processes.

We may now consider which, if any, of the three W-B tests loading this factor measures the strength of this "conditioned attention," and which have loadings merely because they happen to reflect motivational or other influences on the conditioning process. Rapaport's description of "concentration,"

particularly as it applies to PC (30, pp. 230 ff.), appears to provide a tenable psychological identification for Factor IV. While it has been shown that PC actually subsumes three different factors (34), including "maintenance of contact," "maintenance of perspective," and "effect of uncertainty," the latter is also present in OA and its variance in the present sample is probably in Factors III and VI. The former two may be regarded as different qualities of attention and may be related to the question of inward versus outward direction of attention that was left unresolved above. Smykal and Wilson's study of the effect of electroconvulsive therapy (ECT) on the W-B indicates that the most pronounced effect is an improvement in PC performance (39); ECT may easily be regarded as an attempt at one-trial conditioning, for the purpose of improving the patient's attentiveness to psychotherapy and to other appropriate material.

Factor IV appears, then, to be a second-order factor of "concentration" or "conditioned attention," marked by the αI variable, and that will require analysis of a larger matrix for clarification of the first-order relationships.

More extensive interpretation of this factor would appear to require some assumption regarding the meaning of PA, which we prefer to avoid since it would have no direct bearing on our discussion of either of the two EEG variables included in this study.

Factors V and VI: These two factors are not unimportant, but they do not present any loading for either αF or αI which we would want to understand. Factor V is marked by the residual vector for OL, and can be interpreted as depicting the differential ability patterns at the extremes of the NIPR occupational hierarchy. Factor V is very similar to Mundy-Castle's uninterpreted Factor E, differing principally in the reported sign of the loading for OL relative to the rest of the factor. Factor VI is a bi-polar factor contrasting BD (and its customary twin, OA) with V; we would normally have expected these two to provide independent factors, given a sufficient number of variables in the overall factor problem.

Summary

Factor analysis is re-applied, using relatively more rigorous methods, to a 15 x 15 correlation matrix reported by Mundy-Castle and containing 11 Wechsler-Bellevue subtest variables, 2 EEG variables, age and occupational level, for a sample of 34 employees of the South African National Institute for Personnel Research. Six common factors were extracted and subjected to orthogonal rotation in search of meaningful simple structure.

Two age-related factors were found and respectively identified as "Experience" and "Deterioration." (Factors I and II.)

Within the residual four-space, the vectors for alpha Frequency in the EEG and Digit Span performance in the W-B were found to be comparable. (Factor III.) This result is discussed in relation to the excitability cycle hypothesis, primary *vs.* secondary function, and externalization *vs.* internalization.

The vector for alpha Index was found to have a near perfect communality in the residual three-space, and is interpreted as measuring (inversely) strength of "Conditioned Attentiveness." (Factor IV.) Picture Completion in the W-B is judged to depend partially on this factor.

The remaining two factors are of minor interest since they are probably mixtures of things that could not be distinguished in this study using only 15 variables and 34 cases.

It is suggested that a proper interpretation for common factors, when there have not been enough variables to preclude the existence of specific factors, is in terms of dynamic mechanisms presumptive of a cause-effect relationship between loaded variables, rather than in terms of hypothetical underlying variables. Factors I, IV, and V can be used to illustrate this principle.

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